Refining the Southern California 3D Model in the Los Angeles Area Using Seismic Waveforms

2004 Annual Project Summary

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1 Investigation Undertaken

1.1 Receiver functions of stations in the Los Angeles Area

We retrieved waveform recordings of all earthquakes with magnitude larger than 5 between 2000 and 2003 from the Data Center of Southern California Earthquake Center. 35 broad-band stations in the Los Angeles Area were used (Fig. 1). After a quick visual inspection of all the waveforms, 22,144 three-component waveforms from 663 events were selected based on their good signal-to-noise ratios. From the event distribution shown in Fig. 2, one can see that we have good azimuthal coverage, especially for the west and northwest directions.

We first measured P arrivals by cross-correlating vertical components of waveforms of each earthquake. It served as a data quality check to identify instrument problems such as polarity reversal. We then used an iterative time-domain deconvolution technique to compute receiver functions [*Kikuchi and Kanamori*, 1982; *Ligorria and Ammon*, 1999]. This deconvolution technique has better performance than other deconvolution methods especially for noisy data. A graphics user interface program were written using TCL/TK language to allow us to visually examine deconvolution traces of each station. This was done by sorting traces by back-azimuth and checking for similarities among receiver functions from clustered events. Bad deconvolution traces were discarded. In total we obtained 9,199 receiver functions, about 260 receiver functions per station on average.

For each station, we stacked receiver functions if they cluster in the coordinates of back-azimuth and ray-parameter. We then plotted back-azimuthal profiles of radial and tangential receiver functions. Fig. 3 shows an example for station USC. This lets us to examine shapes of receiver functions and their variation with directions. The first 10 s of receiver functions

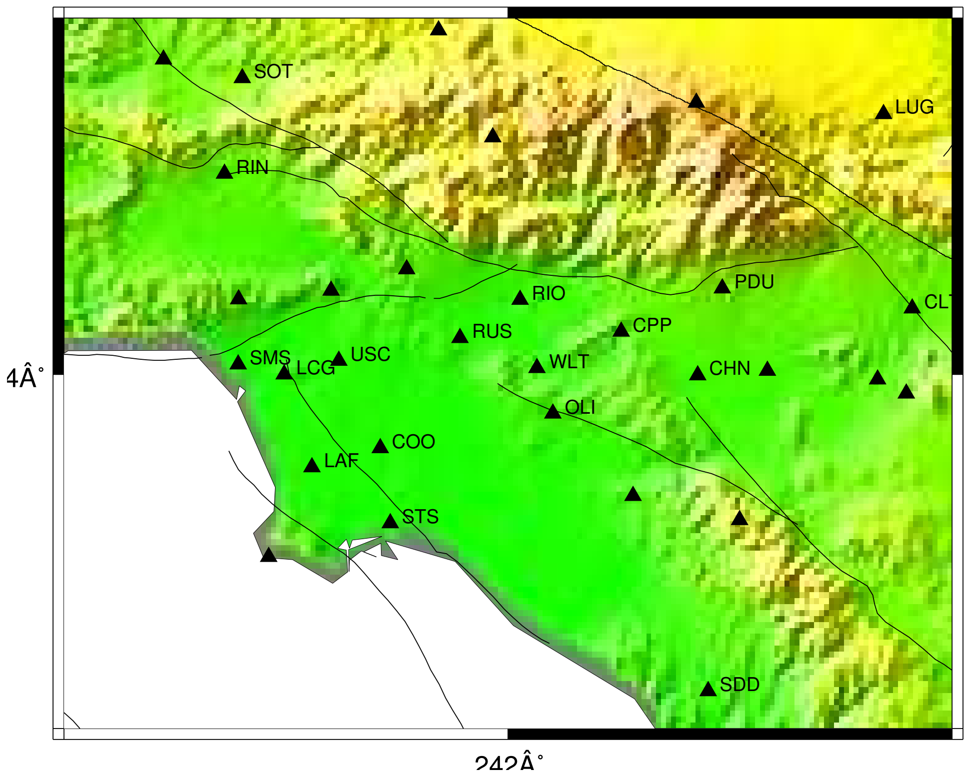

Figure 1: Distribution of broadband seismic stations of the TriNet network (black triangles) in the Los Angeles area. Stations whose receiver functions show existence of low velocity surface layer (sedimentary layer) are labeled by their station name.

following the direction P wave are very diagnostic to existence of sedimentary layer, which tends to reduce the amplitude of the direct P wave and generates large amplitude P-to-S converted waves on the radial component. These converted waves reverberate in the sedimentary layer and dominate the first 10 s of receiver function. Large tangential amplitudes are often observed due to lateral variation of basin thickness.

We have identified 20 stations whose receiver functions show characteristics of basin effects similar to those at station USC (Fig. 3). Their locations are shown in Fig. 1 and correlate well with distribution of sedimentary basins in the Los Angeles areas.

1.2 Inversions of receiver functions

We conducted inversions of the first 10 s radial receiver functions for upper crustal velocity structure under each station using the Neighborhood Algorithm (NA) [*Sambridge*, 1999]. It is a multi-dimensional parameter space search algorithm that only needs solving the forward problem and does not require computing partial derivatives of receiver functions. We used a two-layer upper crustal model with the bottom layer (the basement) velocities fixed (V_p

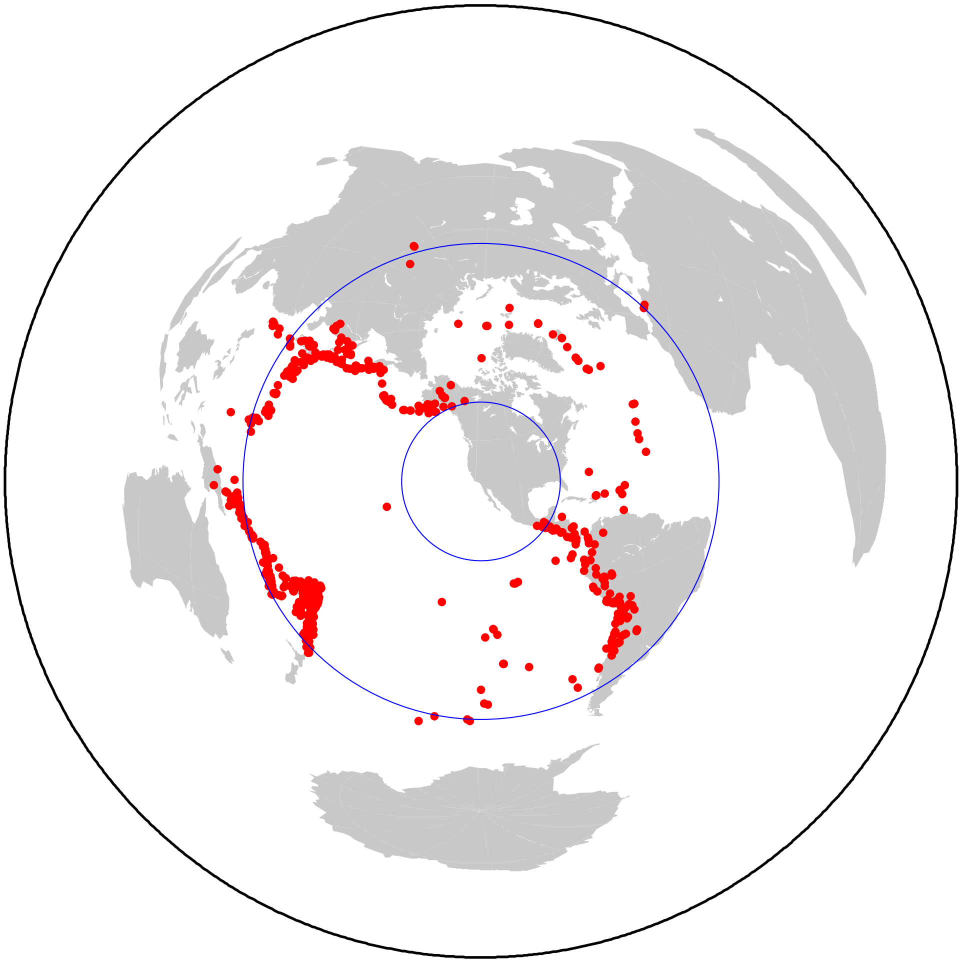

Figure 2: Distribution of 663 teleseismic events between 30° and 90°in epicentral distance.

6 km/s and V_s 3.43 km/s). The velocities in the top layer are assume to be linear functions of depth with a constant V_p/V_s ratio. We searched for the best thickness, top and bottom shear velocities, and V_p/V_s ratio of the sedimentary layer that produce the best fit in a least-square sense to observed receiver functions. Theoretical receiver functions are calculated using the Haskell propagator matrix method [*Haskell*, 1964]. Because of good incidence angle sampling for the SE direction (back-azimuths 110° to 140°) and the NW direction (back-azimuth 290° to 330°), we did inversions of receiver functions of these two directions separately. A wide range of parameters (basin depths from 0.5 to 8 km and shear velocities from 0.2 to 3.0 km/s) were searched.

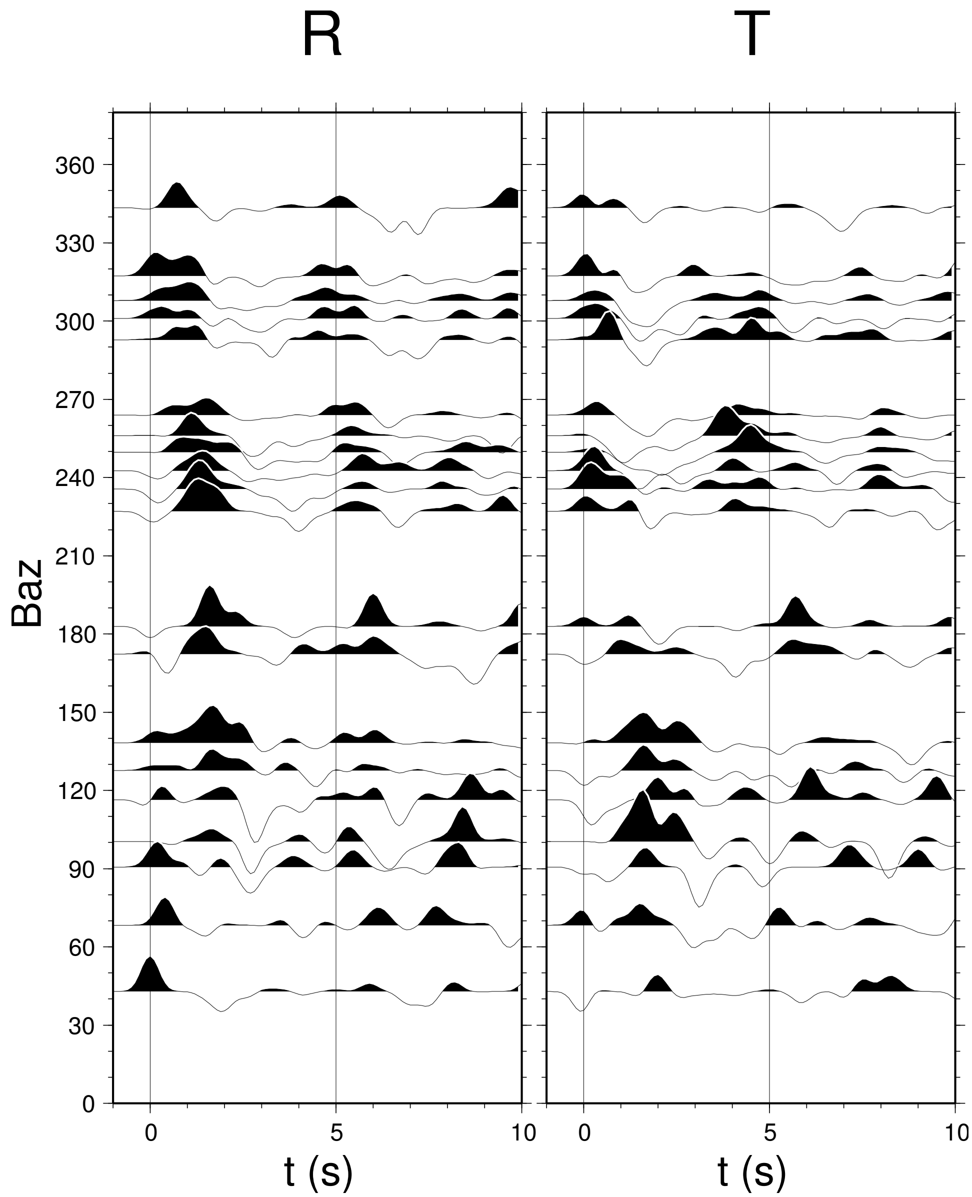

Figure 3: Radial and tangential components of receiver functions of station USC.

2 Results

Fig. 4 shows inversion results for station USC and their comparison with the SCEC-3D (version 3) model. For the NW direction, the best model has a basin thickness of 2.3 km and a V_p/V_s ratio of 2.36. The best model from the inversion of SE receiver functions shows a slightly thicker sedimentary layer (2.8 km). The obtained V_p/V_s ratio is close to that of the SCEC-3D model but the basin thickness is much less than that of the SCEC-3D model (6 km). The theoretical receiver functions of the best models match main features of the observed radial receiver functions (Fig. 5).

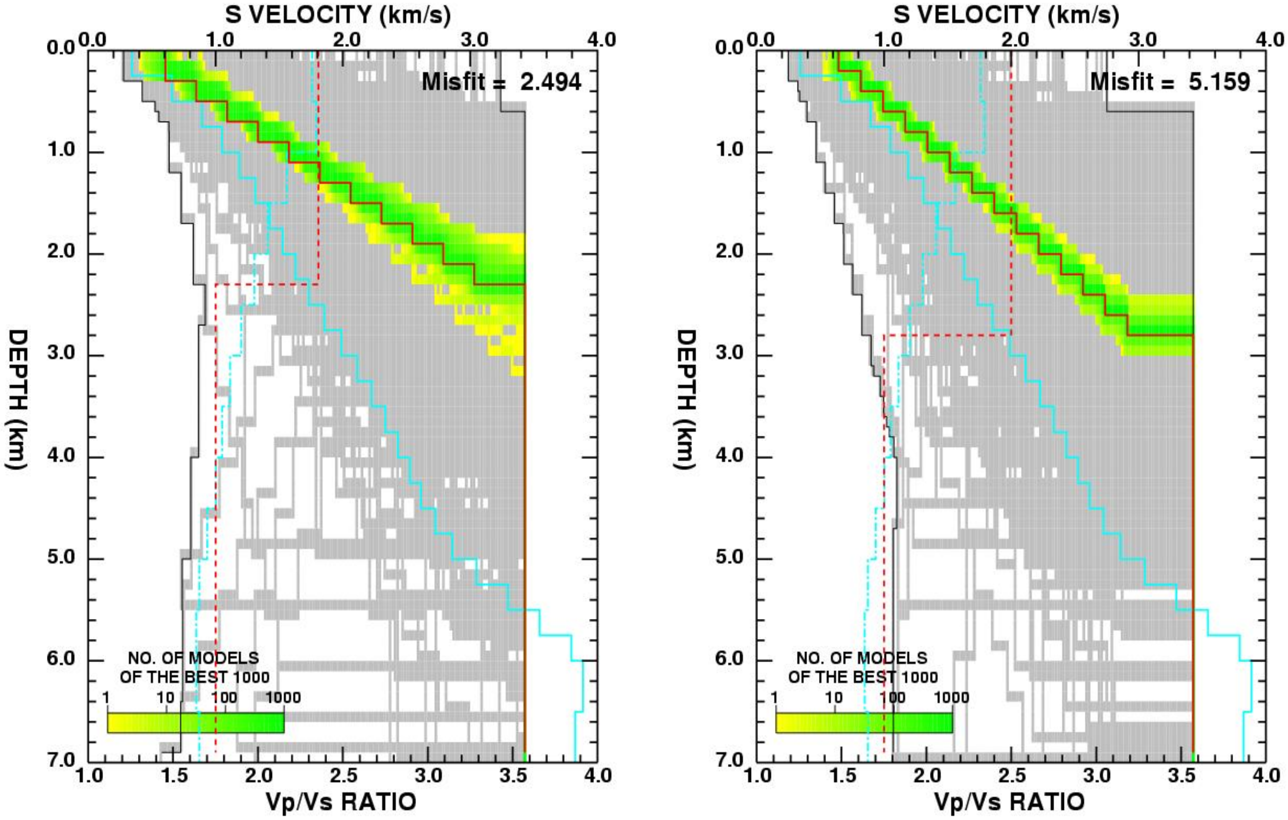

Figure 4: NA inversion results for the NW (left) and SE (right) directions. The Gray area shows all models searched in the NA inversion and the colored area represents the best 1000 models. The red solid line is the best shear velocity model and the red dashed line is the best V_p/V_s model. The corresponding SCEC-3D models are shown in blue color.

3 Non-technical summary

We processed 22,144 three-component waveforms from 663 global large earthquakes between 2000 and 2003 and obtained 9,199 high quality receiver functions of 35 broadband stations in the Los Angeles area. We identified 20 stations whose receiver functions show characteristics of sedimentary basin effects. Their locations correlate well with distribution of sedimentary basins in the Los Angeles areas from geology. Preliminary modeling of their receiver functions from two opposite directions shows that sedimentary basins have high V_p/V_s ratio of 2.3 to 2.5. The SCEC-3D model seems to over-estimate the sedimentary basin thickness near station USC.

4 Reports published

Chu, R., and L. Zhu, 2003, Refining the southern California 3D model in the Los Angeles area using seismic waveforms (abstract), AGU 2003 Fall meeting, San Francisco, CA.

5 Data availability

Preliminary CCP crustal image along the LABSE line in PDF format and station delays in ASCII format are available in ftp.eas.slu.edu/pub/lupei/labpse.grd.tz. For detailed information, contact Lupei Zhu (email: lupei@eas.slu.edu, Tel: 314 977-3118).

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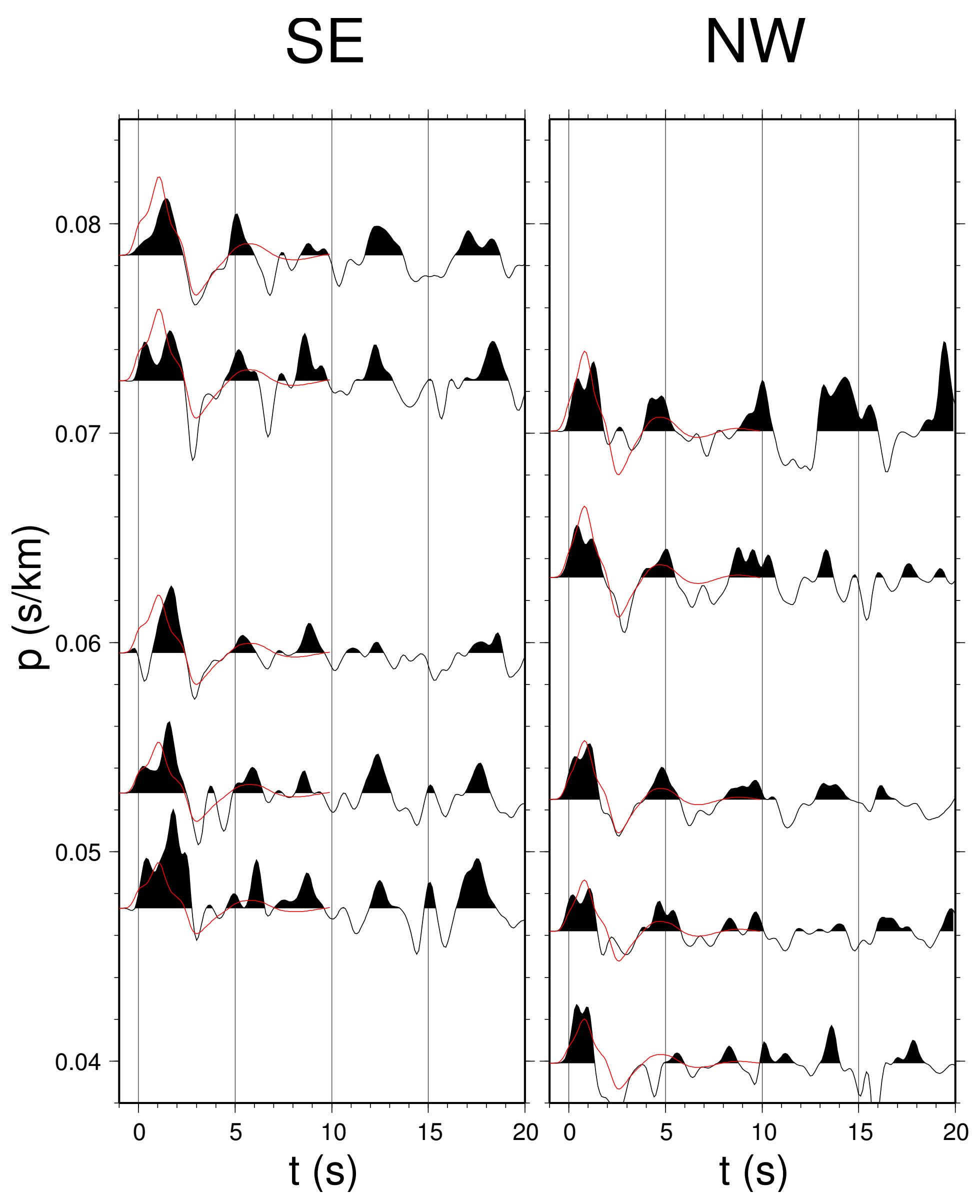

Figure 5: Stacked observed receiver functions from the SE and NW directions. Red colored traces are theoretical receiver functions of the best velocity model from the NA inversions (Fig. 4).